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ABSTRACT

Research supports the premise that various mathematical topics can be categorized as being performed better by the left or right brain hemisphere. This study examined the effect of left and right brain hemispheric lateralization exercises upon course grades in two sections of Analysis I (beginning calculus for mathematics/science majors) at a small liberal arts college for black women. In one section, 25 students were given two different types of logical-verbal left brain activities. In the other section, 30 students were given two different types of viseo-spatial right brain activities. Torrance's "Style of Learning and Thinking" was used to assess students' lateralization preferences. There was no significant difference in course grade means between the two treatment groups. However, left dominant subjects in the left brain treatment group scored higher on course grade than left dominant subjects in the right brain treatment group. Also, right dominant subjects in the right brain treatment scored higher than right dominant subjects in the left brain treatment group. Laterality differences in course grades, Scholastic Aptitude Test (SAT) scores, high school grade point average (GPA), and college GPA were also examined. Included are 27 references and examples of right brain and left brain activities. (DC)

DO LEFT OR RIGHT BRAIN TRAINING EXERCISES HAVE THE GREATER EFFECT UPON COLLEGE CALCULUS ACHIEVEMENT ?

PAPER PRESENTED AT THE ANNUAL MEETING OF

THE NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS

APRIL 7, 1988

CHICAGO, ILLINOIS

BY

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ABSTRACT

This study examined the effect of left and right brain hemispheric lateralization exercises upon course grades in two sections of Analysis I (beginning calculus for mathematics/science majors) at a small liberal arts college for Black women. In one section (n = 30), students were given two different types of logical-verbal left brain activities. In the other section (n = 25), students were given two different types of viseo-spatial right brain activities. Torrance's Style of Learning and Thinking (SOLAT) was used to assess subjects' lateralization preference. There was no significant difference in course grade means between the two treatment groups. However, left dominant subjects in the left brain treatment group scored higher on course grade than left dominant subjects in the right brain treatment group. Also right dominant subjects in the right brain treatment group scored higher than right dominant subjects in the left brain treatment group. Perhaps by exercising the dominant hemisphere, students were able to increase the efficiency of the preferred hemisphere. When the treatment was opposite a student's laterality, perhaps a cognitive conflict was initiated between the hemispheres. Laterality differences in course grades, SAT scores, high school GPA, and college GPA were also examined.

Calculus plays a major role in the curriculum of colleges and universities. It has been estimated that more than half of all undergraduate degree programs require some form of calculus. Since many students choose their college major by its mathematics requirement, calculus may act as Sell's (1973) "critical filter" severely limiting their choice of college major and career. The purpose of this research was to study the effects of left and right brain exercises on the calculus achievement of students enrolled in a first semester college course.

Hemispheric Specialization

Hemispheric specialization refers to the set of functions performed best by each hemisphere of the brain. A large body of research concurs that the left hemisphere is primarily responsible for written and spoken language, abstract symbolism, number operations, linear processing, rational decision making, and deductive logic. The right hemisphere is primarily responsible for spatial skills, pattern recognition, creativity, parallel processing, intuitive decision making, and inductive logic.

Research supports the premise that various mathematical topics can be categorized as being performed better by the left or right hemisphere. Franco and Sperry (1977) found that geometry is processed better by the right hemisphere while arithmetic operations appear to be processed better by the left hemisphere. In another publication, Sperry (1972) reported:

> In addition to being all non-verbal activities, all those various tasks at which the right hemisphere is found to be superior, seem to a large extent to involve a direct apprehension and cognitive processing of spatial form and spatial relations as such (p. 131).

Gardner (1983) found that the left hemisphere has the ability to read and produce the symbols of mathematics while the right hemisphere understands numerical relations and concepts. Davidson (1984) concurred that the right hemisphere is better at grasping the "big picture" while the left hemisphere is better at remembering the details of mathematics.

Hemispheric Lateralization

Hemispheric lateralization is defined as a learner's preferred hemisphere of control (Zdenek, 1983). In almost every task, electrical activity is present in both hemispheres of the brain. But even though both hemispheres are working on the same task, they work in different ways, with one dominant hemisphere being responsible for decision making. Various lateralization tests (verbal, figural, eye movement, dichotic listening, EEG, PET and CAT scans, magnetic resonance, et al), position a learner on a continuum: L________+________R. It has been reported that a learner's lateralization can be affected by specific activities, exercises, and instructional practices (Belzunce, 1980).

PURPOSE AND RATIONALE

Prior Studies

Previous research by this author examined the relationship between hemispheric lateralization and success/failure in three college mathematics courses (Miller, 1986). In this study it was found that in Precalculus I (college algebra), successful students were usually left dominant, while unsuccessful students were usually right dominant. Successful Precalculus II (trigonometry, conics, vectors, complex numbers) students were usually right dominant, and the unsuccessful students were usually left dominant. In Analysis I (beginning calculus for mathematics/science majors), no significance difference in the successful students was found between left and right dominant learners, but 70% of the unsuccessful students were left dominant. The results of this study indicate that perhaps left brain skills are a necessary but not sufficient condition for calculus mastery. That is, calculus excellence requires a strong right brain component in addition to left brain ability.

Jarsonbeck (1984) studied the effects of right-brain mathematics instruction on fourth grade students and found more right dominant learners in the lower achieving group, and more left dominant learners in the higher achieving group. She also found that students in the control group (left brain instruction) achieved higher scores if they were left dominant, and students in the experimental group (right brain instruction) achieved higher scores if they were right dominant. This study indicates the importance of matching hemispheric instruction style to student hemispheric learning style. Davis (1984) was unable to show hemispheric laterality or viseospatial proficiency to be a predictor of mathematical ability in young children. Harmon (1984) failed to correlate cognitive style (as defined in three different ways) to calculus achievement in college students. His study did not specifically investigate the correlation between hemispheric lateralization and calculus achievement.

These studies, and others, piqued my interest in the question of whether lateralization exercises would have an effect on calculus achievement. The conflicting results indicate a particular need for more research in this area.

Spatial Ability

The relationship between spatial ability and mathematics ability has been an important research question in recent years. Although some researchers report no correlation between spatial skills and overall mathematical performance (Very, 1967; Lean & Clements, 1981), many others reported positive correlations (Burdett, Lane & Dratt, 1979; Fennema & Sherman, 1977; Fennema & Tartre, 1985; Guay & McDaniel, 1977; Reyes & Padilla, 1985; Sherman, 1979; Sherman, 1983). Smith (1964) found spatial ability to be related to the acquisition of high-level mathematical concepts, but not to the acquisition of low-level mathematical skills. Many studies have found a connection between mathematical thinking and mental manipulation of geometric figures (Fennema, 1974; Meserve, 1973; Smith, 1964). Specifically, only one study was found which related spatial ability to calculus achievement, although the research in related fields (geometry, trigonometry, engineering, and physics) leads one to hypothesize a positive correlation. Ferrini-Mundy (1987) investigated the effects of two types of spatial training on calculus achievement. Although she found no treatment effect on calculus achievement, she did conclude that spatial training may benefit performance in certain areas of calculus for women more than for men. For these reasons, right brain exercises involving spatial skills were chosen for the study.

Research Questions

The present study addressed several of the hypotheses generated by the research on the relationship of hemispheric lateralization to mathematics achievement, spatial ability to mathematics achievement, and the potential of lateralization exercise training. The specific research questions were:

1. Are there differences in first semester calculus course grades between students who performed left brain (verbal logical) exercises and students who performed right brain (viseo-spatial) exercises, after adjustments have been made for initial academic differences ?

2. Are there differences in first semester calculus course grades between left dominant learners who performed left brain exercises and left dominant learners who performed right brain exercises ?

3. Are there differences in first semester calculus course grades between right dominant learners who performed right brain exercises and right dominant learners who performed left brain exercises ?

4. Are there differences in calculus course grades between left and right dominant learners ?

5. Are there differences in Verbal, Math or Total SAT scores between left and right dominant learners ?

6. Are there differences in high school or college grade point averages between left and right dominant learners ?

METHOD

Subjects

Students who registered for the first semester calculus course at Spelman College randomly enrolled in either the 9:00 am section (n = 25) or the 1:00 pm section (n = 30), depending on their course schedule or other personal reasons. Spelman College is a historically Black, small, private, liberal arts college for women. All the subjects in the study were women. Both sections were taught by the author. Both sections met daily for 55 minutes during a 15 week semester.

The Calculus Course

Differential and integral calculus are taught over two semesters at the college. A departmental syllabus is used to standardize the curriculum.

Five chapter exams are given approximately ι ꜫe weeks apart. Each version of the chapter exam is composed of randomly varied combinations of questions developed by individual instructors. A comprehensive final exam is administered. The course grade was determined as follows: 60% chapter exams, 25% comprehensive final exam, 15% quizzes, homework, and class participation.

Treatments

The 9:00 am section was randomly selected to receive the right brain exercise treatment, and the 1:00 pm section received the left brain exercise treatment. There was no control group.

In accordance with Clement's (1981) conclusion that a variety of spatial activities was more likely to improve students' spatial skills, two different exercises were chosen. The right brain treatment consisted of two types of viseo-spatial activities: figural sequences and figural analogies. Each type of exercise was performed for approximately seven weeks. Both two dimensional and three dimensional figures were used. These exercises had been identified by the publisher (Midwest Publications, 1986) as viseo-spatial (right brain) development activities. This is in agreement with current research in this field. (See Appendix I for examples of each type.) The following themes were emphasized while performing the spatial activities: visual discrimination among figures, mental manipulation of figures, extended practice on spatial tasks, speeded performance of spatial tasks, progression from simple to complex tasks, and students'alternative strategies for performing spatial tasks.

Similarly, the left brain treatment consisted of two types of verbal-logical exercises: deductive logic puzzles and word benders. Each type of exercise was performed for approximately seven weeks. Midwest Publications (1986) identified these activities as logical-verbal (left brain) development activities. This is in agreement with current research. (See Appendix II for examples of each type.) These themes were stressed while performing the logic activities: deductive propositional logic, counterexamples, and students' alternative strategies for producing deductive conclusions.

Procedure

At the beginning of the semester, a description of the study was given to the class along with the results of the author's previous study. All students were invited, but not required to participate in the study. The level of participation was 100%. The students were then administered a hemispheric lateralization survey. Both exercise treatments were administered three times per week during the 15 week semester, for ten minutes a day in class, and approximately twenty minutes of homework three times per week. Homework was reviewed in class, collected, and checked. Other than the treatments described above, the classes were kept as uniform as possible with respect to teaching methods, assignments, grading procedure, and evaluation frequency, and evaluation instruments. At the end of the semester, the following data was collected on each subject: high school grade point average, Spelman cumulative grade point average, verbal SAT score, math SAT score, total SAT score, and course grade. Since each of the three students who withdrew from the course left within the last two weeks of the semester because of failing averages, their course grades were treated as "F's".

Instruments

Your Style of Learning and Thinking (SOLAT) was used to assess subjects' hemispheric lateralization. This 40 item, multiple choice survey was developed by Torrance et al (1979), and has since been normed and referenced and is distributed by Scholastic Testing Service under the name Human Information Processing Survey (HIPS). This instrument was used to place a subject on the right or left half of the lateralization continuum.

RESULTS

The research questions shall be addressed individually:

1. Are there differences in first semester calculus course grades between students who performed left brain (verbal-logical) exercises and students who performed right brain (viseo-spatial) exercises, after adjustments have been made for initial academic differences ?

The first step was to determine if there were significant differences in the academic backgrounds of the two treatment groups which should be accounted for in the analysis. Using T-tests, no significant differences were found with respect to high school grade point average ($p < .243$), Spelman college grade point average ($p < .166$), verbal SAT ($p < .980$), math SAT ($p < .422$) or total SAT ($p < .608$) scores. I then examined the hemispheric lateralization of the two treatment groups. T-tests showed no significant differences between the lateralization scores of the two treatment groups.

Convinced that there were no significant initial academic differences between the treatment groups, T-tests were used to test for differences in the means of the calculus course grades. Although the left brain treatment group performed slightly better (2.000 vs. 1.9677), there was no significance difference between the two treatment groups ($p < .926$).

2. Are there differences in first semester calculus course grades between left dominant learners who performed left brain exercises and left dominant learners who performed right brain exercises ?

T-tests were used to test for differences in the means of course grades of the groups. When students' lateralization scores were divided at the mean of the continuum, the left dominant learners who performed the left brain exercises scored significantly higher than left dominant learners who had performed the right brain exercises ($p < .060$).

When the lateralization scores were determined at the point one half of a standard deviation on either side of the continuum mean, the number of subjects decreased but the same trend emerged ($p < .074$).

3. Are there differences in first semester calculus course grades between right dominant learners who performed right brain exercises and right dominant learners who performed left brain exercises ?

When students' lateralization scores were divided at the mean of the continuum, the right dominant learners who performed the right brain exercises scored higher on course grade than right dominant learners who performed the left brain exercises ($p < .361$). Although the T statistic was not significant, it is consistent with the predicted direction.

When the lateralization categories were determined at the point one half of a standard deviation on either side of the continuum mean, the number of subjects decreased but the same trend emerged at a better level of significance ($p < .174$).

4. Are there differences in calculus course grades between left and right dominant learners ?

The two treatment groups were put together, and were then divided into left ($n = 31$) and right ($n = 23$) dominant learners by their lateralization scores with respect to the mean of the continuum. T-tests were used to test for mean differences in course grade. Although the left dominant group scored higher (2.3548 vs. 2.1739), it was not significant ($p < .627$).

When the lateralization categories were determined at the point one half of a standard deviation on either side of the continuum mean, the left dominant learners ($n = 23$) still scored higher than the right dominant learners ($n = 15$), but the difference decreased (2.0870 vs. 2.000) to an inconsequential level ($p < .856$).

5. Are there differences in Verbal, Math or Total SAT scores between left and right dominant learners ?

The two treatment groups were put together, and were then divided into left ($n = 31$) and right ($n = 23$) dominant learners by their lateralization scores with respect to the mean of the continuum. T-tests were used to test for mean differences in Verbal, Math, and Total SAT scores.

When lateralization was determined at the mean of the continuum, the right dominant group scored higher on Verbal SAT (424 vs. 394), although not significantly ($p < .194$). When the lateralization categories were determined at the point one half of a standard deviation on either side of the continuum mean, the right dominant learners ($n = 23$) scored even higher than the left dominant learners ($n = 15$), and the difference increased (439 vs. 393). However, this difference was not significant ($p < .120$).

When lateralization was determined at the mean of the continuum, the right dominant group scored higher on Math SAT (481 vs. 470), although not significantly ($p < .675$). When the lateralization categories were determined at the point one half of a standard deviation on either side of the continuum mean, the right dominant learners ($n = 23$) scored even higher than the left dominant learners ($n = 15$), and the difference increased (492 vs. 470). However, this difference was not significant ($p < .544$).

Naturally, the right dominant group scored higher on Total SAT in both lateralization schemes. When divided at the mean of the lateralization continuum, the difference (906 vs. 864) was not significant ($p < .356$). When the groups were further lateralized, the right dominant scores increased (931 vs. 863) which led to a greater difference between the two group scores. However, this difference was still not significant ($p <.258$).

6. Are there differences in high school or college grade point averages between left and right dominant learners ?

The two treatment groups were put together, and were then divided into left ($n = 31$) and right ($n = 23$) dominant learners by their lateralization scores with respect to the mean of the continuum. T-tests were used to test for mean differences in high school grade point average and college grade point average.

Left dominant learners had higher high school gpa's (3.26 vs. 3.08) although this difference was not significant ($p < .495$). Using this same lateralization scheme, right dominant learners had higher college gpa's (2.81 vs. 2.60) than left dominant learners. This difference, however was still not significant ($p < .171$).

When the groups were further lateralized, different results emerged for high school gpa. Right dominant learners scored slightly higher than left dominant learners (3.09 vs. 3.04). T-tests did not show this difference to be significant ($p < .753$). At the college level however, right dominant learners continued have higher gpa's (2.92 vs. 2.51) than left dominant learners. This difference was significant at the $p < .100$ level.

DISCUSSION

Since spatial ability has been shown to be positively correlated with high level mathematical ability, and since the author's previous study indicated a positive correlation between right dominant lateralization and calculus achievement, it was hypothesized that the right brain (viseo-spatial) treatment group would outperform the left brain (logical-verbal) treatment group. This hypothesis was not proven statistically. Perhaps calculus achievement was affected more by a learner's lateralization than by the type of hemispheric lateralization exercises performed.

The most striking results of this study came when I examined subjects' laterality crossed with their treatment group. Course grades were significantly higher when students' hemispheric laterality matched their treatment group. Perhaps by exercising the dominant hemisphere, students were able to increase the efficiency of the preferred hemisphere. When the treatment was opposite a student's laterality, perhaps a cognitive conflict was initiated between the hemispheres. A possible educational implication would be to structure our classrooms such that we match hemispheric teaching style to student hemispheric learning style. The case for enhancing college students' calculus scores through the type of training employed in this study was not supported by the results, but the feasibility of fostering improvement by matching learning style to teaching style is indicated.

The correlations between hemispheric laterality and various academic standards yielded some surprising results. It was expected that left dominant learners would outperform right dominant learners on the Verbal SAT. Perhaps the reason right dominant learners outperformed left dominant learners on both parts of the SAT is that right brain thinkers are able to synthesize the individual subjects they were taught into a cohesive "big picture". Contrary to what was expected after reviewing reported research, right brain thinkers outperformed left brain thinkers on every academic measure except high school grade point average. Perhaps high school subjects and evaluation methods are designed to encourage left brain thinking, while college curriculums are designed to encourage right brain thinking. Perhaps left brain thinking is a prerequisite for academic achievement, but an additional right brain component is necessary for academic excellence.

This study has contributed to the general topic of hemispheric lateralization differences through its findings as well as through the directions defined for future work. A deeper examination of the relationship between right brain thinking and calculus achievement is warranted. Logical-verbal and viseo-spatial training may be important components of a well rounded mathematics curriculum. Additional research could answer the questions of whether hemispheric training programs enhance mathematical learning and, if so, how should they be incorporated into the curriculum ?

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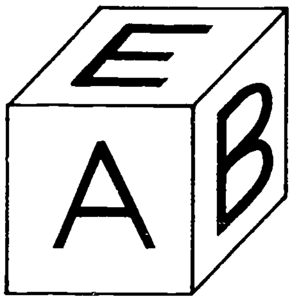
APPENDIX I

EXAMPLES OF RIGHT BRAIN ACTIVITIES

26.

a.



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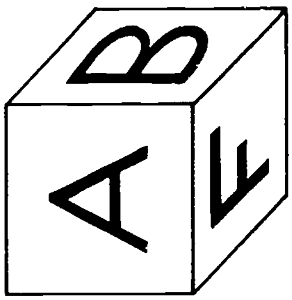

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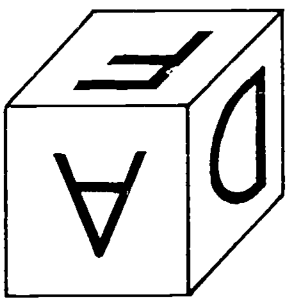

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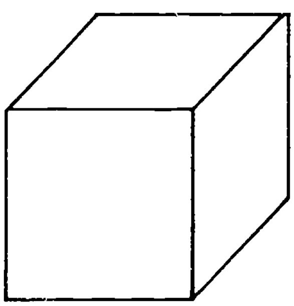

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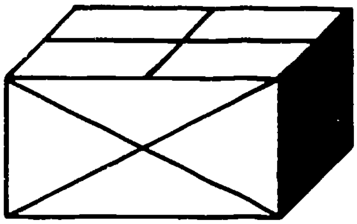

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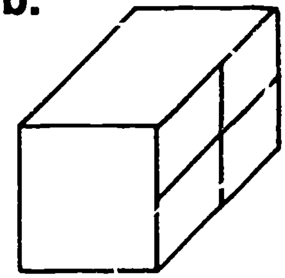

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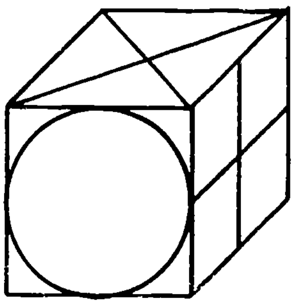

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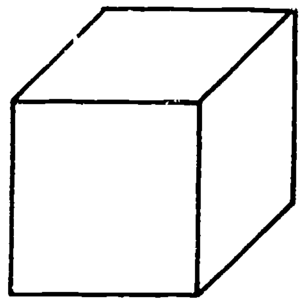

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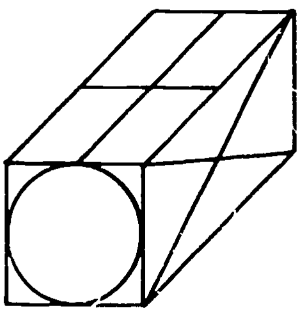

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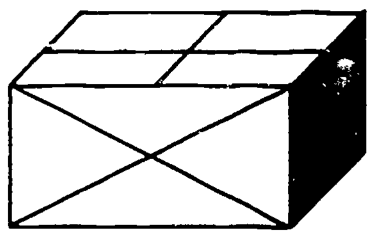

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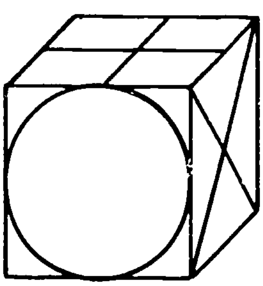

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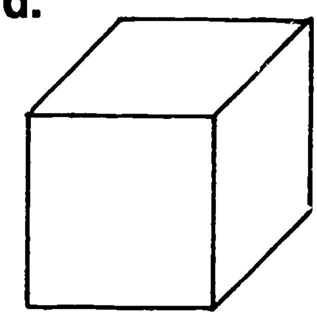

APPENDIX II

EXAMPLES OF LEFT BRAIN ACTIVITIES

15.

Amelia, Barbara, Corwin, and Darby each have a favorite kind of TV program. These are stories about doctors, police stories, science-fiction adventures, and westerns. Each person likes everything about his or her favorite kind of program. From the clues below, find each person's favorite kind of TV program.

1. Corwin doesn't like horses.

2. Darby doesn't like cowboys or detectives.

3. Amelia doesn't like mountains or stories about crooks.

4. Amelia and the person who likes stories about doctors are in different grades.

OPPOSITE OR DISTINCTLY DIFFERENT

11. H I L L — VALLEY

_ O _ _ — ROOM

_ _ _ O — WEAK

O _ _ _ — TANNED

O _ _ _ — FEMALE

O _ _ _ — HILL

_ _ O _ — SIR

O _ _ _ — SPRY

O _ _ _ — WENT

_ _ _ O — HOTEL

O _ _ _ — DRY

_ O _ _ — PICK UP

O _ _ _ — SMOOTH

_ O _ _ — WALK EVENLY

O _ _ _ O O — COMPLEX

_ O _ _ _ _ — FULL SIZE

E X A M P L E — THE FULL TEXT